

of oscillation diminished. It was easy to see that a large oscillation would strain the cords to a greater height above the slider than would be called for in a smaller oscillation. The truth of this surmise was proved by the success of the remedy applied. Instead of cords I used two pairs of broad tapes, and instead of a solid slider I made one in two halves, embracing the rod in the centre and nipping the concurrent tapes on either side between their opposed faces, being clamped together by thumb-screws beyond the tapes on either side. Here the slider had no firm hold on the rod beyond the accuracy of its fit, which served to prevent torsion, but had firm hold on the pairs of tapes, pinching them with especial accuracy at the upper edge of the slit in which they lay between the two halves, and reducing the hinge there to a narrow line no thicker than the pairs of tapes instead of the gross thickness of the cords which they superseded. The improvement of the pendulum's performance on paper was very striking. When well adjusted, it was scarcely possible from beginning to end to detect any change in the shape of the figure described; *scarcely* possible, I say, for even now our hinge is not a mathematical line, and we do not obtain perfect mathematical accuracy in our results. Further improvement might be obtained by refinement in tapes and slider, or by increasing the total height of the pendulum, or by substituting some other form of hinge; but the form which I have described is so simple, and its performance so good, that I am content to accept its one very small fault for the sake of its many excellent qualities.

Figures 1-12 are the produce of this pendulum thus improved. They are only a few of the most interesting out of an endless variety of interesting curves, and are chosen as characteristic specimens of a series too extensive to be fairly represented except by a much larger number of illustrations. Figures 1 and 2 represent the proportion 1 : 3, the lowest that is easily attainable without a lofter pendulum; and the following pairs of figures show successively the proportions 2 : 5, 1 : 2, 3 : 5, 2 : 3, 3 : 4. Each of these is illustrated by two figures exhibiting the two chief types of the curve proper to that proportion. They may be termed the cusped type and the looped type. It will be seen that the two cusps in the first figure of each pair are opened into loops in the second, and that each loop in the first is doubled in the second. Between these two typical forms we have an infinite series of intermediate forms possessing features of great interest, those nearest the cusped type especially being characterised by a peculiar "watered" appearance, due to the intersection of two sets of lines very slightly inclined to one another. This is seen, for example, in Fig. 3, which errs a little from the perfect type.

Accuracy of proportion between the two periods of vibration could only be arrived at by repeated trials. The sliding-clamp sufficed for coarse adjustment, but for fine adjustment it was found necessary to attach a subsidiary weight below the large one in some way admitting of considerable range of position, so as to alter minutely the position of the centre of gravity. A heavy iron nut travelling easily on a screw-thread cut on the depending shaft that carried the pen supplied this want, and greatly facilitated the attainment of the utmost accuracy at command.

With a pendulum only seven or eight feet high, there is great difficulty in obtaining the curves that correspond to any proportions lower than 1 : 3, because the slider cannot be brought within a certain distance of the centre of gravity, which lies somewhere in the middle of the lead. To obtain the proportion 1 : 3, that is, to make the pendulum swing three times across for every one swing to and fro, we must lower the slider within a foot of the centre of gravity (the length of the pendulum varying as the square of the period of oscillation), and to obtain the proportion 1 : 4, the distance between the

slider and the centre of gravity must be 1-16th of the height of the pendulum, or only six inches in the present instance; but three or four of those six inches are taken up with the thickness of the lead and the attachments of the tapes, and the rest with the depth of the slider, and so the curve cannot be obtained without a more lofty suspension for the pendulum. This greater elevation I found in the great octagonal room which Sir Christopher Wren built as the chief room of the Royal Observatory in Greenwich Park. By means of two hooks fixed above opposite windows in this room, from which my tapes converged to the middle, I got a height of eighteen feet, and was able to reach such proportions as 1 : 4, 1 : 5, 1 : 6. At this extreme it was really amusing to watch the busy haste of the manifold cross-vibration over-riding the staid gravity that marked the slower oscillation to and fro. To obtain proportions lower yet than these, I should want a great increase in height of suspension; but there is no great inducement to attempt this, as the nature of the curve may be foreseen at a glance, and is marked by extreme simplicity—merely a zigzag or a string of beads.

Some of these experiments with lofty suspension were made on stormy days; and while watching the travels of the delicate pen-point, I could see that their regularity was slightly disturbed by every gust of unusual violence that beat against the high walls.

But this article would never end if I allowed myself to dwell on all the points that called for attention in the course of experiment which I have been describing. I fear I have exceeded due limits already, and feel that I owe an apology to the reader for so large a trespass on his patience. My apology must be the elegance and exquisite symmetry of these natural curves in their admirable obedience to a purely natural law, and the great pleasure I have enjoyed—the sense of high privilege I have felt—in their investigation. I understand that these curves, or some of them, have been demonstrated before, by means of a stream of sand flowing from a hole in the base of a vessel that was used as the weight of the pendulum, and I believe that steel springs of elliptic or oblong cross-section have been made to trace such curves as that which first attracted my attention in the vibration of my slender acacia-twigs; but I am not aware that any specimens of the series have ever before been exhibited in a form that rendered them accessible to the public eye.

HUBERT AIRY

SOME SPECULATIONS ON THE AURORA

IN preparing a lecture on the Aurora Borealis some months ago, I was led to some speculations which may or may not be new, and may or may not be of some value. I will submit them to the readers of NATURE.

I assume of course that the auroral rays extend to great heights above the surface of the earth, that they are sensibly parallel, and that their apparent point of convergence is, generally speaking, that to which the freely-suspended magnet points. In the great aurora of October 24, 1870, this point was close to η Pegasi at 8.30 P.M., coinciding very well with the direction of the magnet.* Remembering that this aurora was witnessed over a large part of the northern hemisphere, and that there was a contemporaneous aurora in the southern hemisphere, and, assuming that at each place the direction of the auroral streamers is approximately parallel to the magnet, we must conceive the earth, during such an auroral display, as a globe with streamers of light radiating and diverging from its polar regions, and spreading far out into space. The general direction of these streamers at different spots on the earth will be got by placing a magnet below a sheet of paper and getting the magnetic curves with iron filings,

* To-night it is a few degrees below α Cygni (but not clearly defined) at 11 P.M.

and then describing a circle, to represent a section through the axis of the earth so that the magnet shall occupy the central part, about two-thirds of its diameter. The portion of the magnetic curves outside the circle will cut the circle at different angles, and fairly represent the directions of the auroral streamers.

Now, Arago, in his catalogue of auroras, shows that during the months of September, October, March, and April we are especially favoured with auroras; and that in these months they are both brighter and more frequent than at other times. This periodicity indicates an extra terrestrial origin for auroras. Does it not show that during those months we pass through an auroral region, just as in November and August we pass through meteoric regions, or, in other words, that we intersect a ring of some substance capable of being electrified by the earth in its passage, when there is any change in its magnetic power, and so rendered luminous? But it is impossible not to conjecture that this ring or disc is the very disc which is visible to us as the zodiacal light; for besides the fact of zodiacal light being specially visible during the same months, there is the positive evidence of spectrum analysis to the identity of the substances luminous in the aurora and the zodiacal light. We are led then to the hypothesis that there exists round the sun, and extending as far as our earth, an atmosphere, consisting of an unknown element, a gas of extreme lightness, and that this atmosphere is especially condensed in the form of a disc extending round the sun, but probably not concentric with it. The same element appears to exist in the solar corona, and was also detected in the vague phosphorescent luminosities of the sky on a particular evening, by, I think, Angström.

I wish to suggest, therefore, that catalogues of auroras may, like catalogues of meteors, determine auroral regions in the earth's orbit, and that two such regions are, in fact, already shown by Arago's catalogue, and that this periodicity, as well as the results of spectrum analysis, indicate a cosmical origin for auroras.

There is one more point which may be interesting. The luminous streamers have a lateral motion; they shift sideways, and in fact rotate round their pole. Is this motion of rotation always, or even generally, in the same direction? I have not observed it often enough to speak with confidence. But if so, it must have some definite cause, and will be analogous to that of rotation in a definite direction of an electrical current round the pole of a magnet. The earth must be looked upon as a delicate solar electroscope and magnetometer, and the electrical discharge round the earth is stratified, and is in lines and strata that have, perhaps, motions in definite directions.

It may be worth remarking that the 22nd, 23rd, 24th, and 25th of October are the most famous days in the year for auroras, at least in the present century, and that the greatest displays of all on those days have happened at intervals of multiples of eleven years. Last year we had splendid auroras on the 24th and 25th; there is, therefore, some ground for expecting fine auroras on the same nights this year, if the auroral cycle corresponds to the sunspot and magnetic cycles.

J. M. WILSON

NOTES

WE learn from Indianapolis journals, received at the moment of going to press, that the American Association for the Advancement of Science commenced its sittings on the evening of August 21 by an opening address from the retiring president, Prof. T. Sterry Hunt, on the Iron Interests of Indiana, in which he completely sustained every claim that had been made for the State, showing conclusively that it has the elements within its borders from which to secure a manufacturing future that shall make Indiana the mediterranean workshop for the whole country. The sections commenced their sittings on the following day, and San Francisco was fixed on as the next place of meeting. An extra

double number of the *American Naturalist* for September 15 will give a full report of both the opening address and the sectional proceedings. In a future number we shall give an epitome of all matters of interest discussed at the meeting.

M. JANSSEN has been commissioned by the French Government to proceed to the East to observe the total Solar Eclipse of December next. He has, therefore, been compelled to decline the offer made to him by the British Association to take part in the British Expedition.

THE President of the Royal Society has received a telegram from the Government Astronomer, Melbourne, that the Eclipse Expedition will leave that port on November 20.

WE regret that owing to the omission of a sentence, the note respecting the distinguished visitors at Section A of the late meeting of the British Association, read incorrectly in a small proportion of the edition of our last number. We now supply the omission by giving the following probably unexampled list of Senior and Second Wranglers and Smiths' Prizemen who were present:—Adams, Cayley, Challis, Stokes, Hon. J. W. Strutt, Hopkinson, Kelland, Tait, Wilson, Thomson, Maxwell, Sylvester, Clifford, Jack, J. W. L. Glaisher; of these the first nine were Senior Wranglers.

WE learn from the *British Medical Journal* that in accordance with the will of the late Dr. Lacaze a prize of 10,000fr. is to be awarded by the Faculty of Medicine of Paris every second year to the best work on phthisis and on typhoid fever alternately. The first prize will be awarded at the end of the academical year 1871-2, for the best work on phthisis. Essays (with a distinguishing motto and the author's name in a sealed envelope) must be sent in before July 1, 1872. The prize is open to foreigners.

In a paper read before the Natural History Society of Boston (U.S.), Mr. W. T. Brigham gives an account of several remarkable earthquakes that have occurred in New England, with a list of all such phenomena that have occurred in that region from 1638 to 1870. Some of these disturbances appear to have been violent and protracted.

WE understand from the *Geological Magazine* that there will shortly be published a Geological Atlas of England, by Mr. W. Stephen Mitchell. The Atlas will contain the following Maps:—1. Cambrian (of Survey); Lower Cambrian (of Sedgwick). 2. Lower Silurian (of Survey); Middle and Upper Cambrian (of Sedgwick). 3. Upper Silurian (of Survey); Silurian (of Sedgwick). 4. Old Red Sandstone; Devonian. 5. Carboniferous Limestone; Yoredale Beds. 6. Millstone Grit; Coal Measures. 7. Permian (of Survey); Pontefract Group (of Sedgwick). 8. New Red Sandstone; Rhætic (Penarth). 9. Lias. 10. Lower Oolite. 11. Middle Oolite. 12. Upper Oolite. 13. Wealden; Neocomian. 14. Gault; Upper Greensand; Chalk and Chalk Marl. 15. Eocene. 16. Crag. 17. Alluvium. 18. Bone Caves. 19. Metamorphic (?). 20. Igneous. The Maps will be printed in colours, each Map exhibiting only the range of one formation, and the names of places on the formation. In some few cases, where it is requisite, as a clue to the locality, to introduce the names of places near, but not on, the formation, these will be printed in a different type. The Maps (11½ in. by 9½ in.) are based on a photographic reduction of the last edition of the Greenough Map, which is published under the direction of a committee appointed by the Geological Society. In all cases where, through researches more recent than this last edition, any changes have been adopted in the grouping of the beds, this atlas conforms with the latest alterations. The revision of the proofs of particular maps has been kindly promised by Mr. W. Boyd Dawkins, F.R.S., Mr. W. Whitaker, Mr. H. Bauerman, Mr. J. W. Judd, Mr. Charles Moore, Mr. W. T. Aveline, and others. Letter-press will accompany each map, giving in a tabulated form the subdivisions of the formations, the